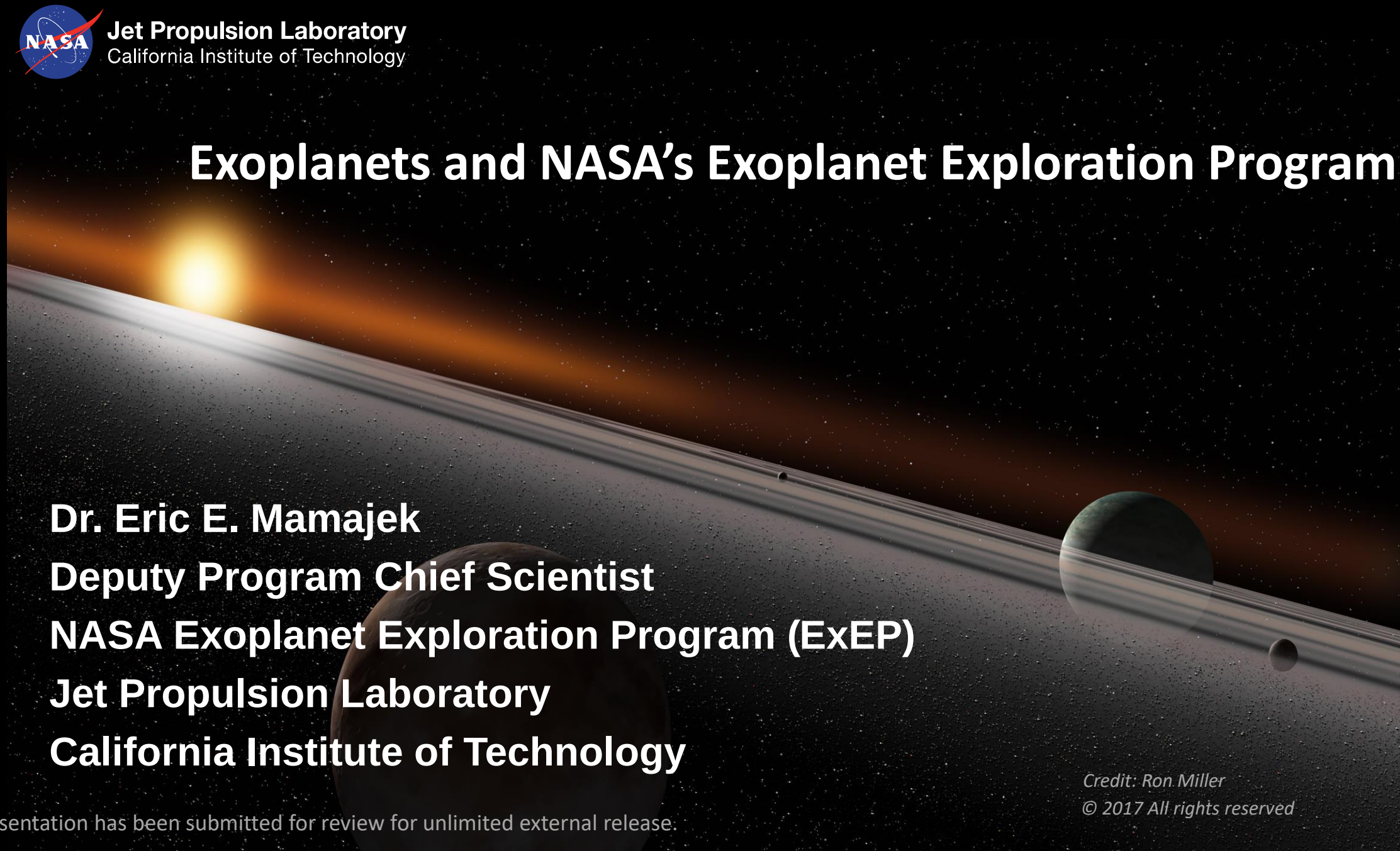

Jet Propulsion Laboratory
California Institute of Technology

Exoplanets and NASA's Exoplanet Exploration Program

Dr. Eric E. Mamajek
Deputy Program Chief Scientist
NASA Exoplanet Exploration Program (ExEP)
Jet Propulsion Laboratory
California Institute of Technology

Credit: Ron Miller

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NASA Exoplanet Exploration Program

Astrophysics Division, NASA Science Mission Directorate

NASA's search for habitable planets and life beyond our solar system

Program purpose described in
2014 NASA Science Plan

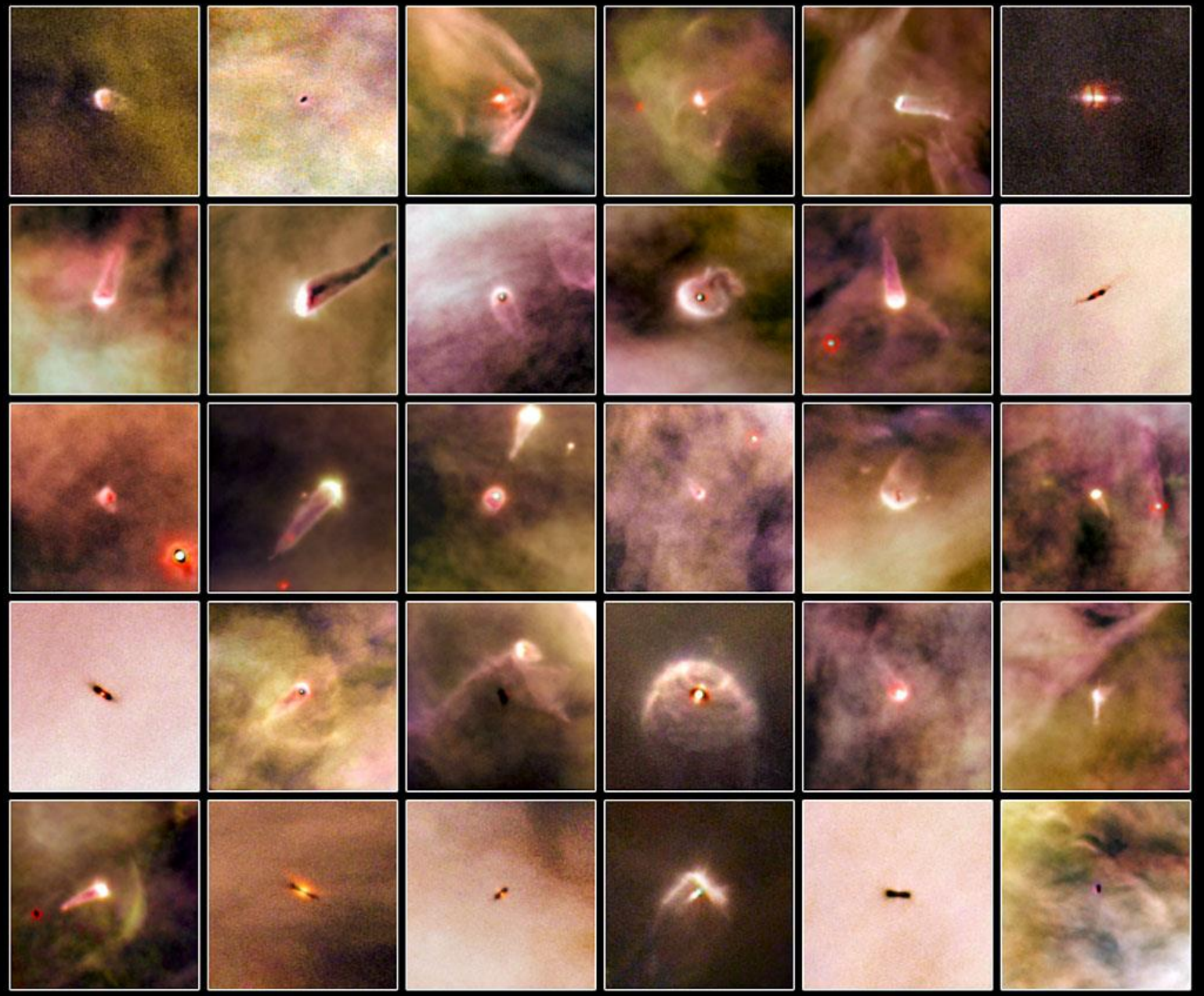
1. **Discover planets around other stars**
2. **Characterize their properties**
3. **Identify candidates that could harbor life**

ExEP serves the science community and NASA by implementing NASA's space science vision for exoplanets

https://exoplanets.nasa.gov

Credit: Andreas Papadopoulos

Credit: NASA



Credit: NASA, ESA, L. Ricci (ESO)

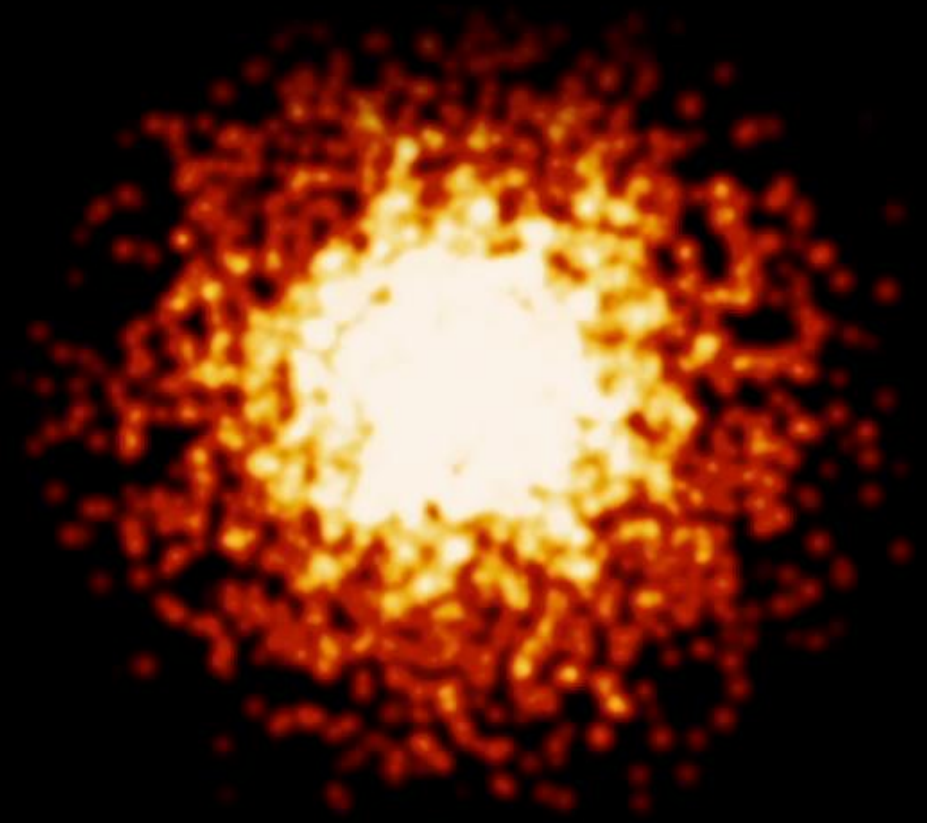
How does one discover planets around other stars?

Doppler Spectroscopy or Radial Velocity Method

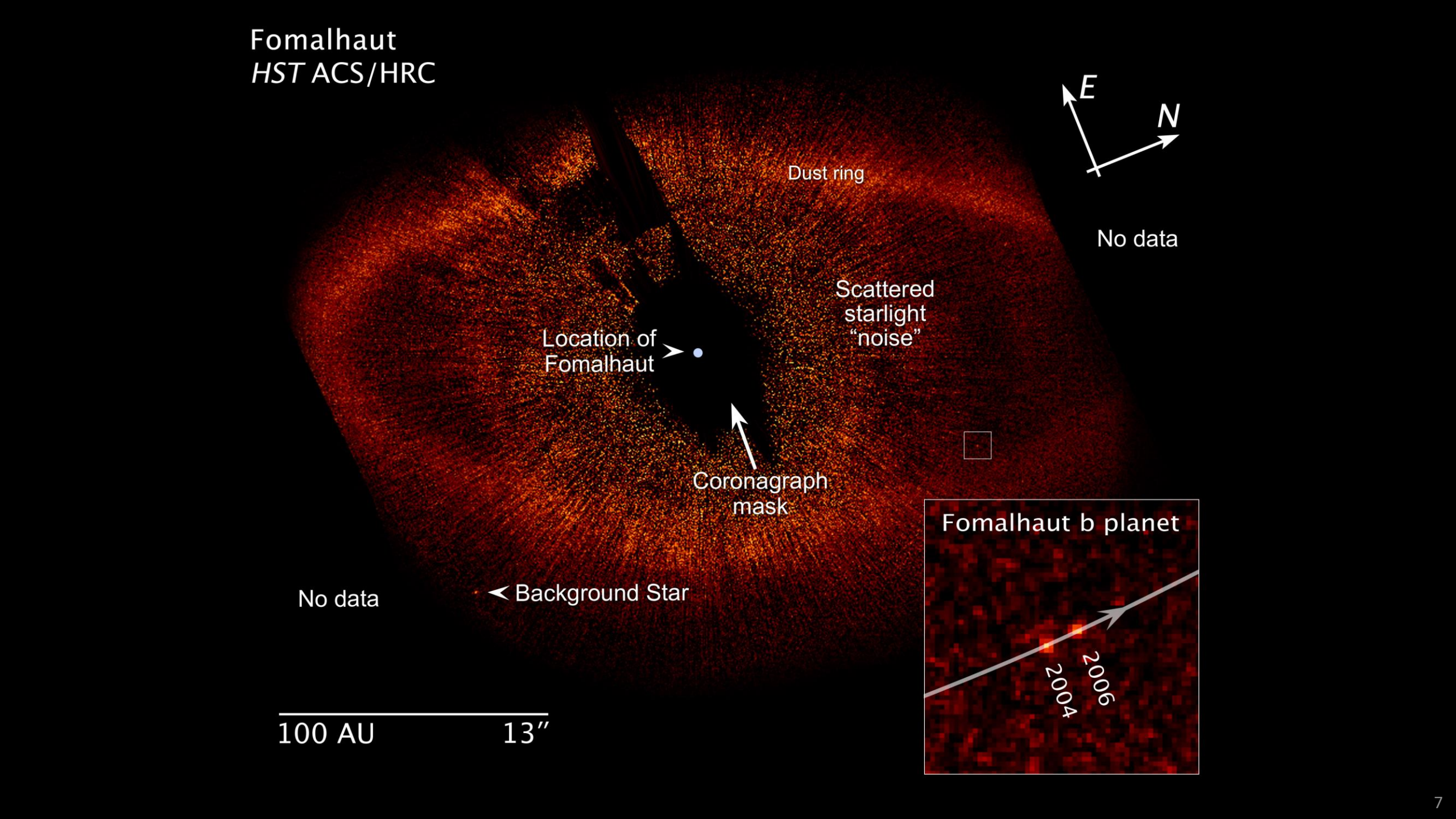
Credit: NASA

Techniques to detect planets around other stars

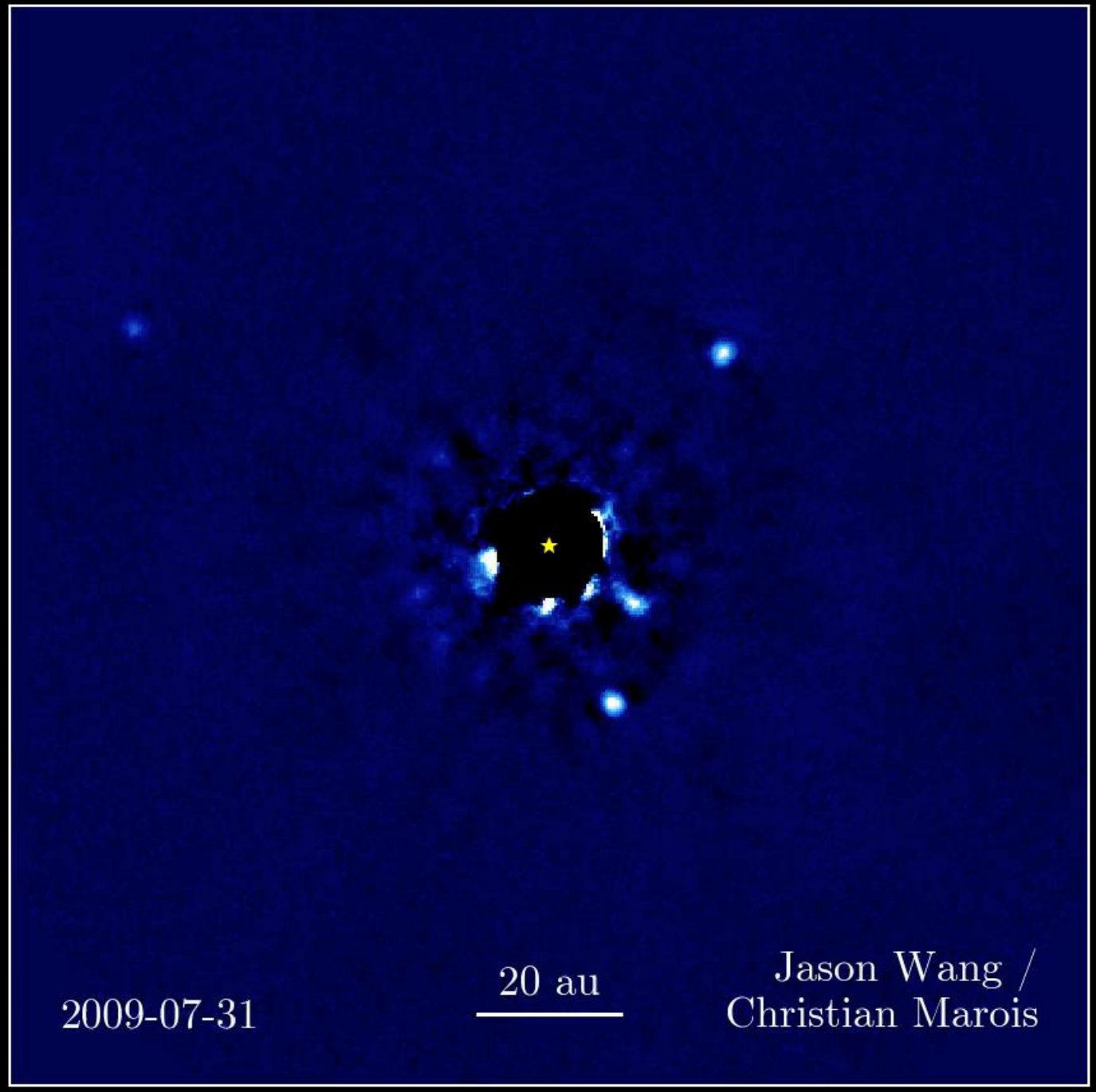
Direct Imaging



Credit: NASA

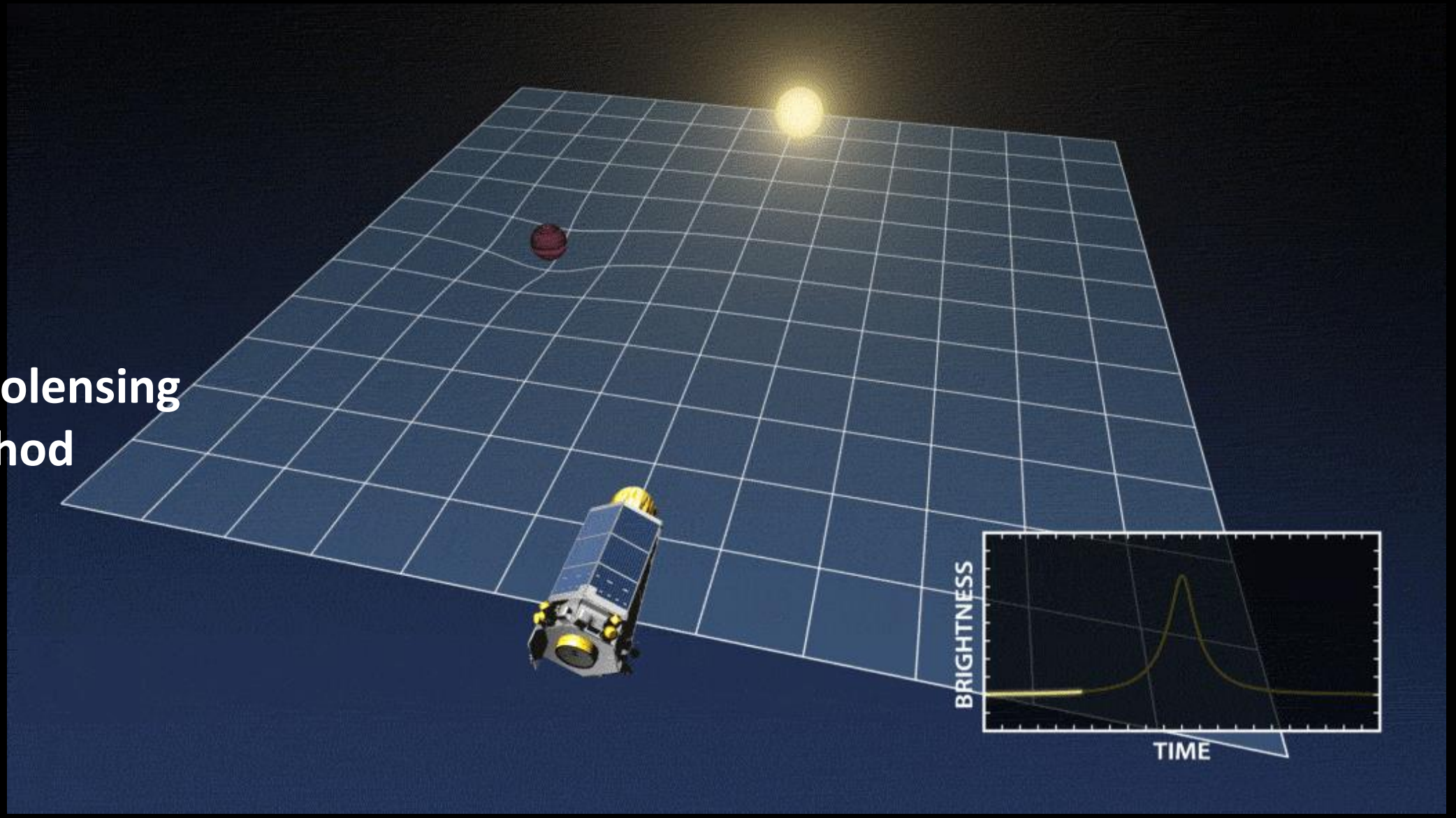

Fomalhaut
HST ACS/HRC
E
N
Dust ring
No data
Scattered
starlight
“noise”
Location of
Fomalhaut
Coronagraph
mask
Fomalhaut b planet
2006
2004
No data
Background Star
100 AU
13″

HR 8799 system:
4 giant planets
(~7-10x Jupiter's mass each)
orbiting a young
(~30 million years)
massive star
(~2x Sun's mass)



Techniques to detect planets around other stars

Microlensing Method



Credit: NASA/JPL-Caltech

Techniques to detect planets around other stars

Transit Method

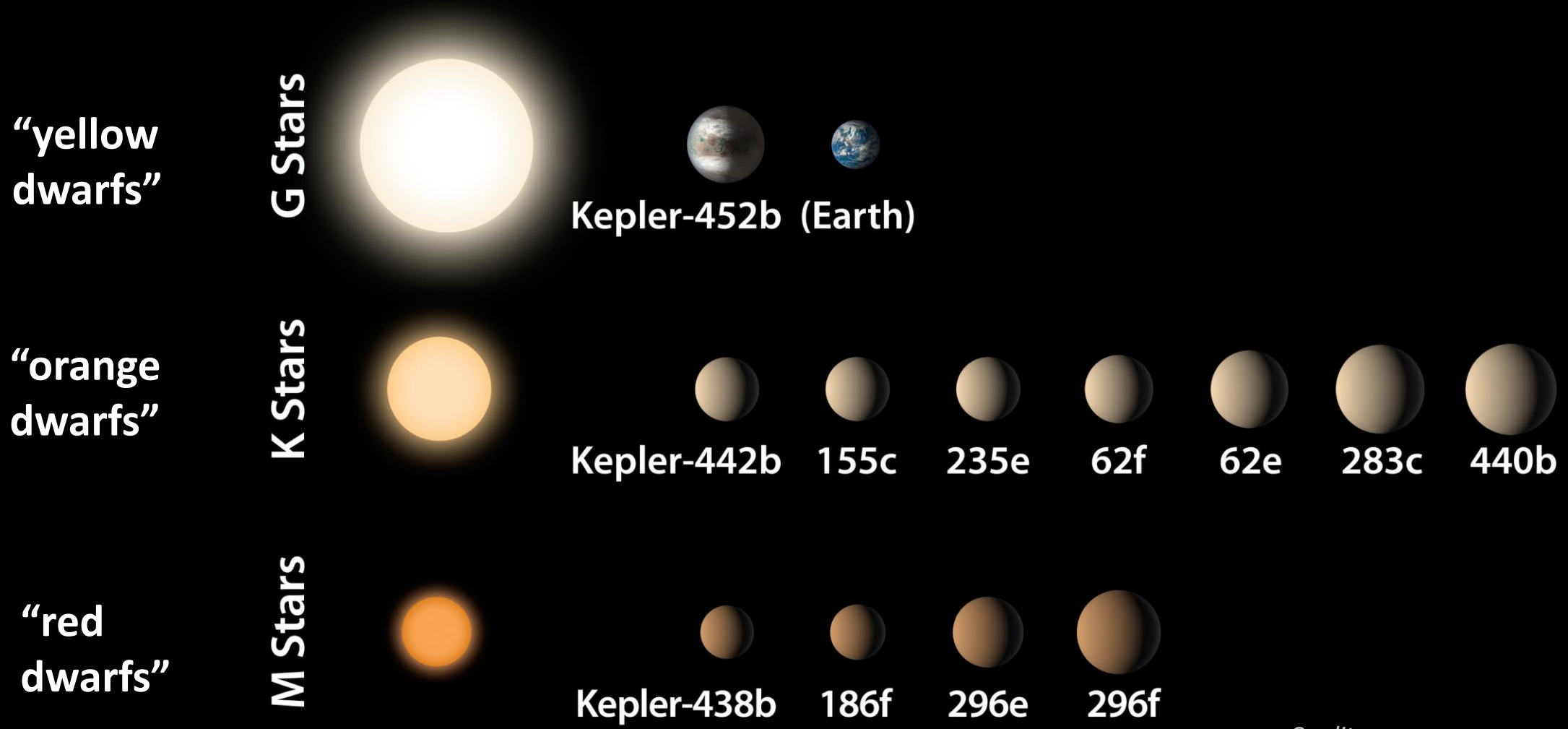
Credit: NASA

Kepler Mission (launched 2009)

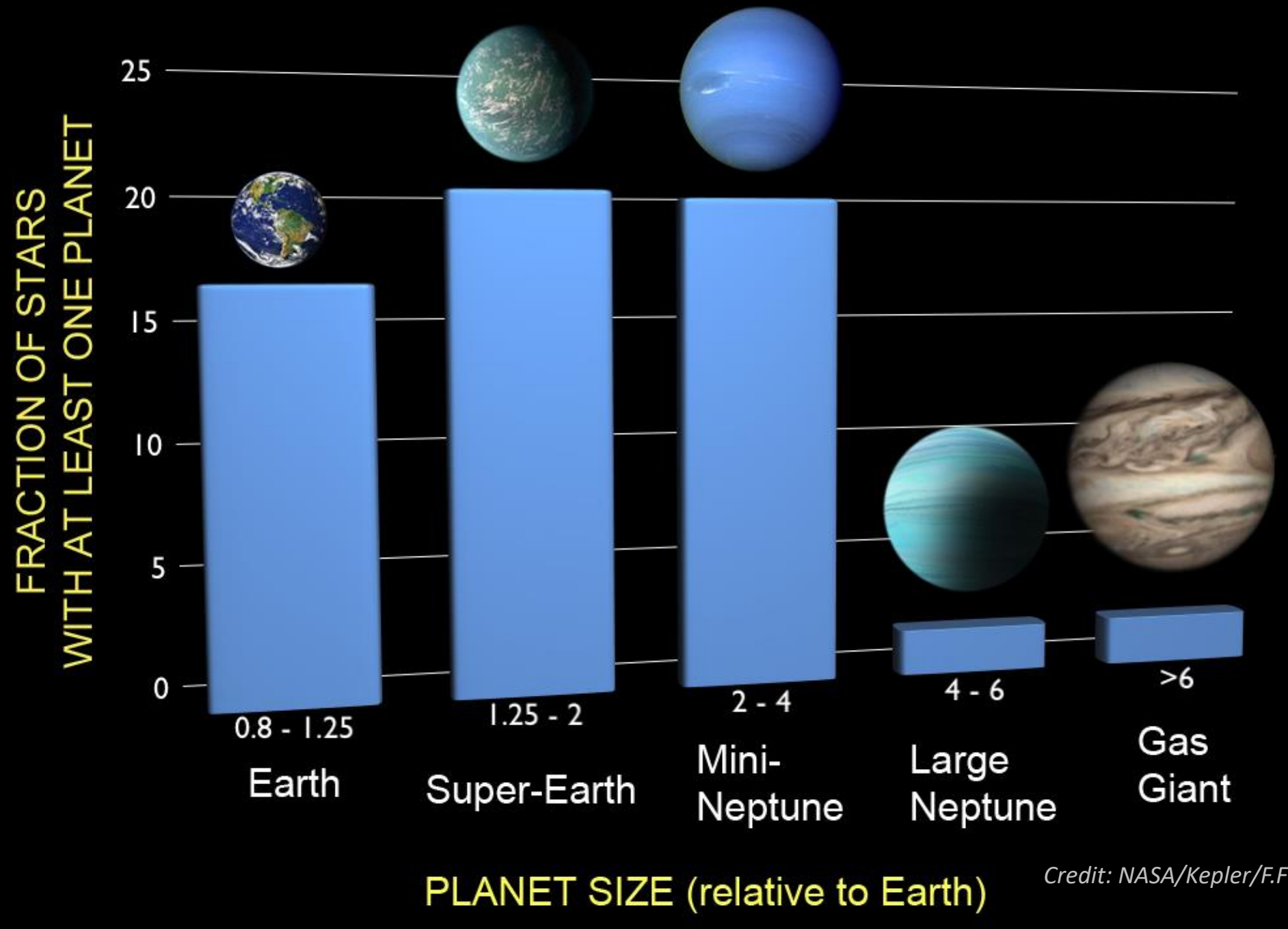
Credit:
NASA/JPL-Caltech/Wendy Stenzel

Kepler's Small Habitable Zone Planets

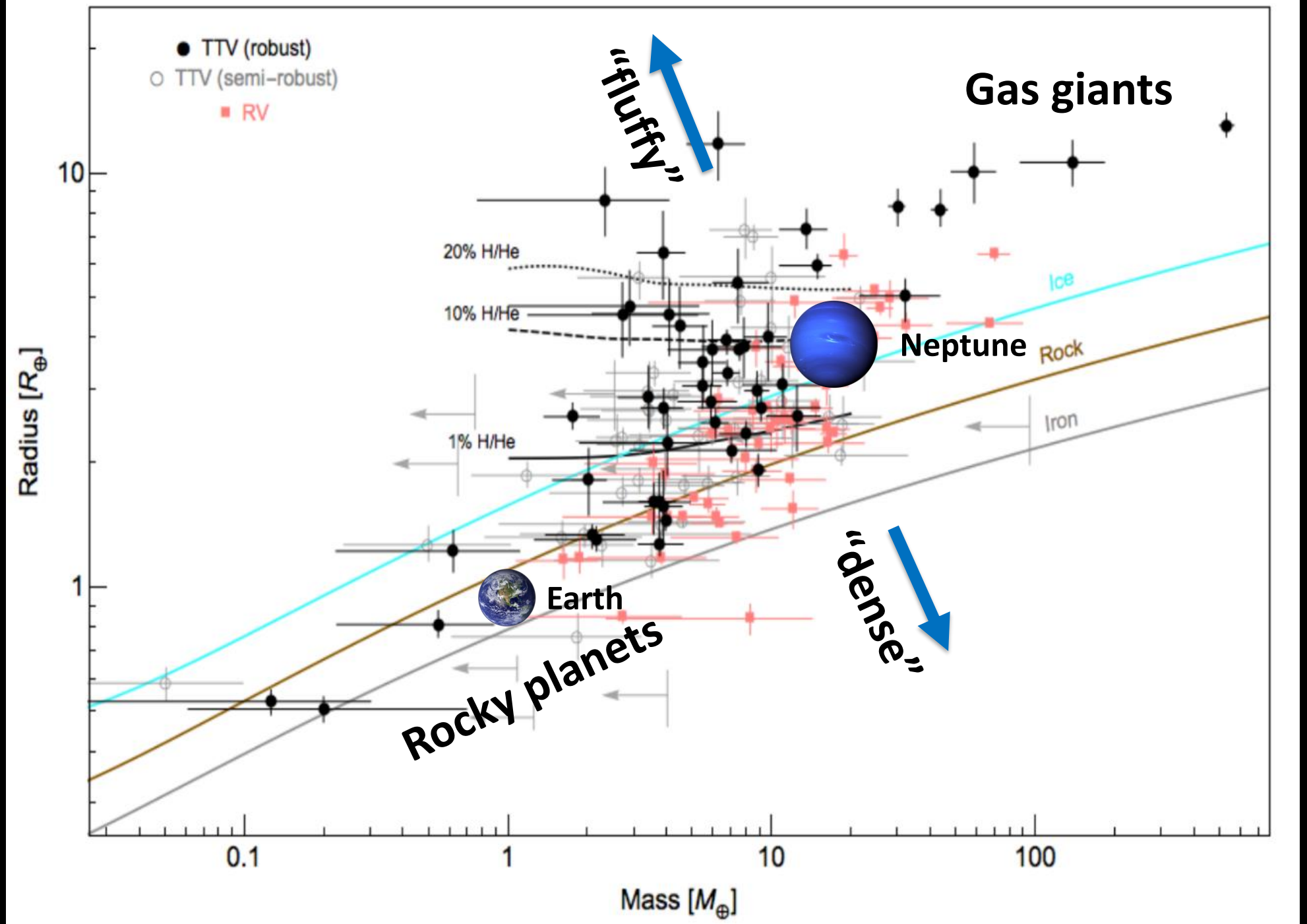
Planets enlarged 25x compared to stars



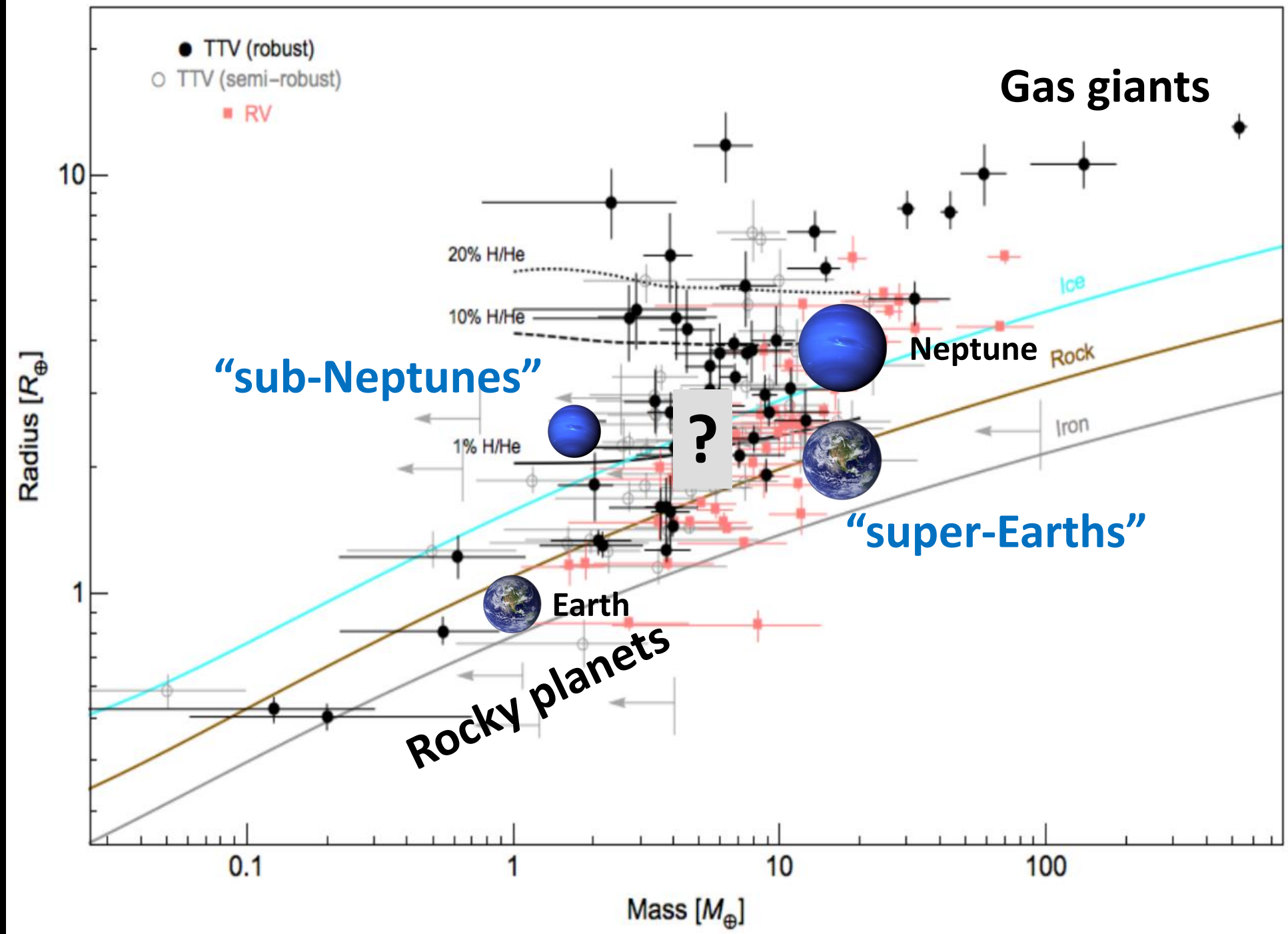
Credit:
NASA Ames/JPL-Caltech/R. Hurt



Credit: NASA/Kepler/F.Fressin



Credit: Hadden & Lithwick 2016



Credit: Hadden & Lithwick 2016

Exoplanet Missions

WFIRST

JWST[2]

TESS

PLATO

Kepler

CHEOPS

New Worlds Telescope

Spitzer

Gaia

Hubble[1]

CoRoT[3]

Habitable Exoplanet Imager?

LUVOIR?

Origins Space Telescope?

NASA Missions

ESA/European Missions

W. M. Keck Observatory

Large Binocular Telescope Interferometer

NN-EXPLORE

Ground Telescopes with NASA participation

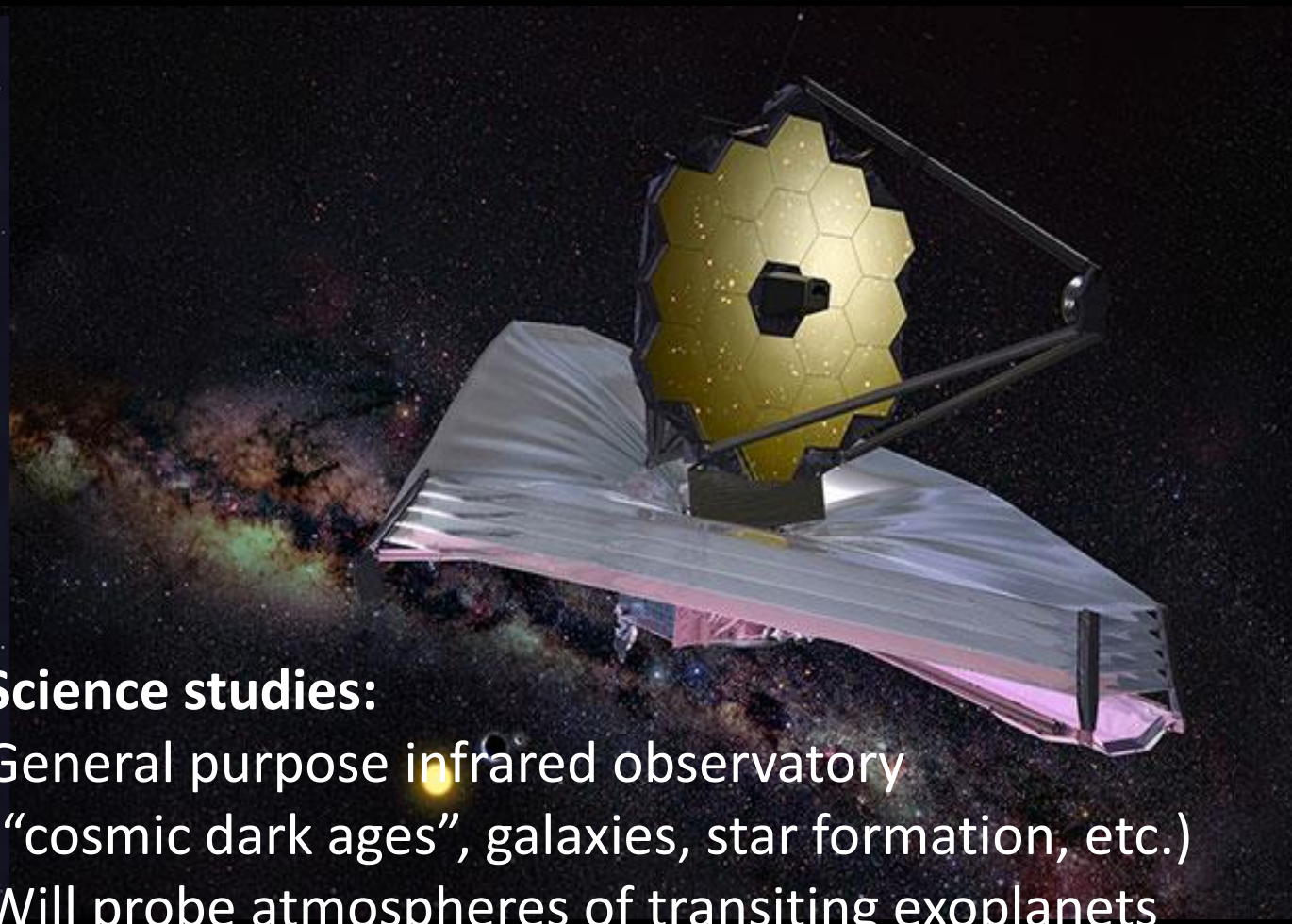
[1] NASA/ESA Partnership
[2] NASA/ESA/CSA Partnership
[3] CNES/ESA

TESS – NASA Explorers Program *(launch 2018)*

Science studies:
Survey most of sky for transiting exoplanets around bright & nearby stars

Credit: NASA, GSFC, MIT

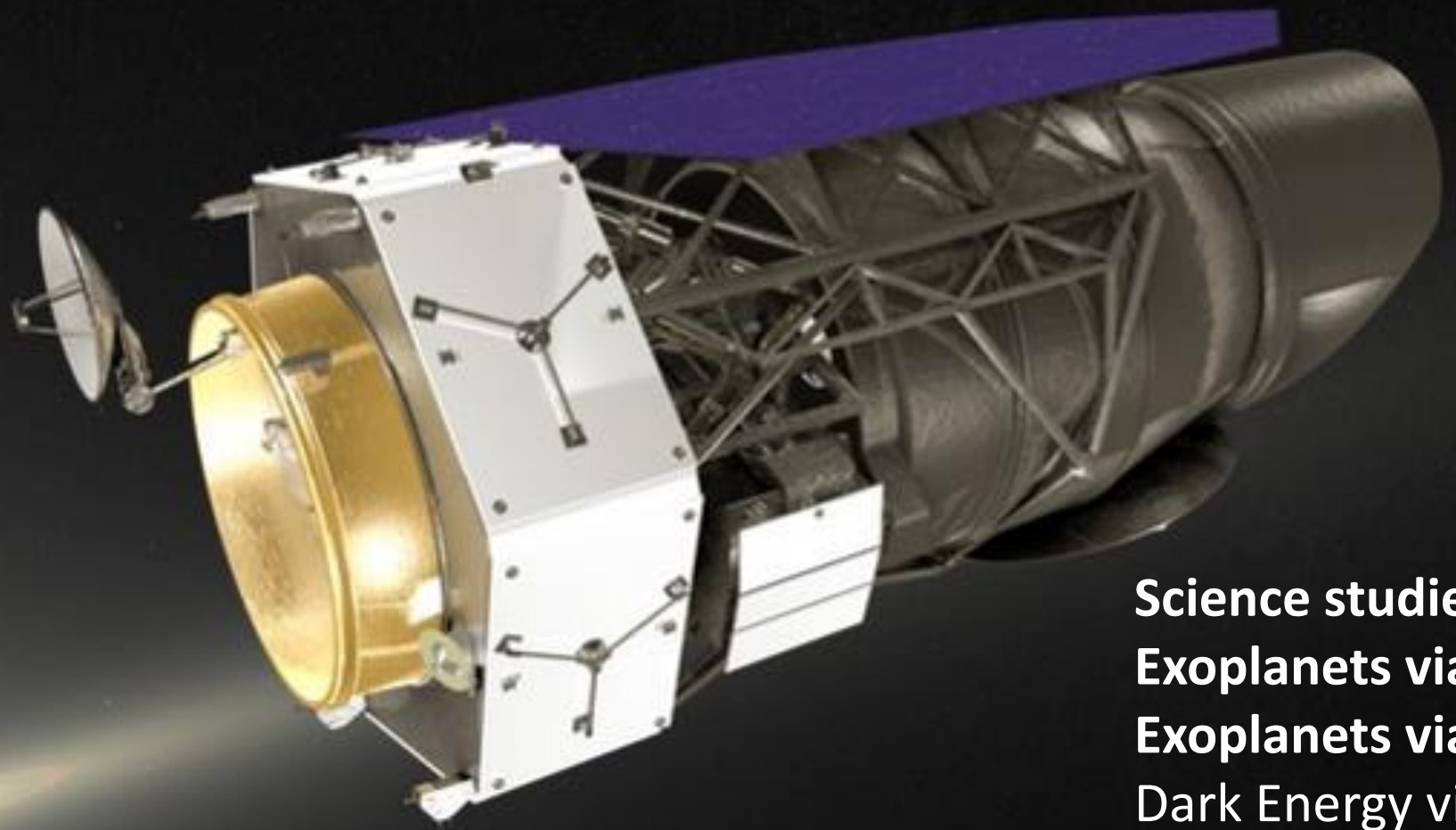
James Webb Space Telescope *(launch 2019)*



Science studies:
General purpose infrared observatory ("cosmic dark ages", galaxies, star formation, etc.)
Will probe atmospheres of transiting exoplanets

Credit: NASA, STSci

WFIRST
Wide Field Infrared Survey Telescope
(launch mid-2020s)

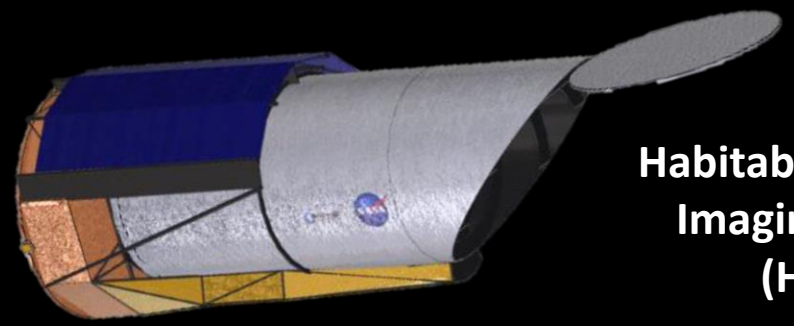


Science studies:
Exoplanets via Microlensing
Exoplanets via Direct Imaging
Dark Energy via Wide-field imaging of galaxies and supernovae

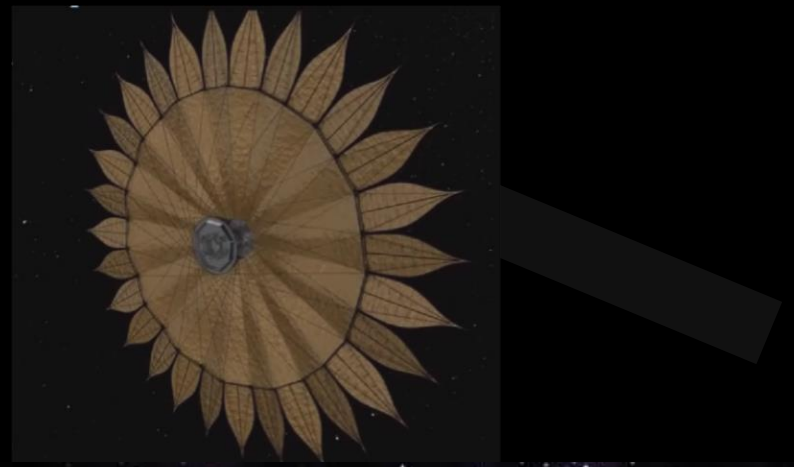
Credit: NASA/GSFC

Starshade Optical Shield

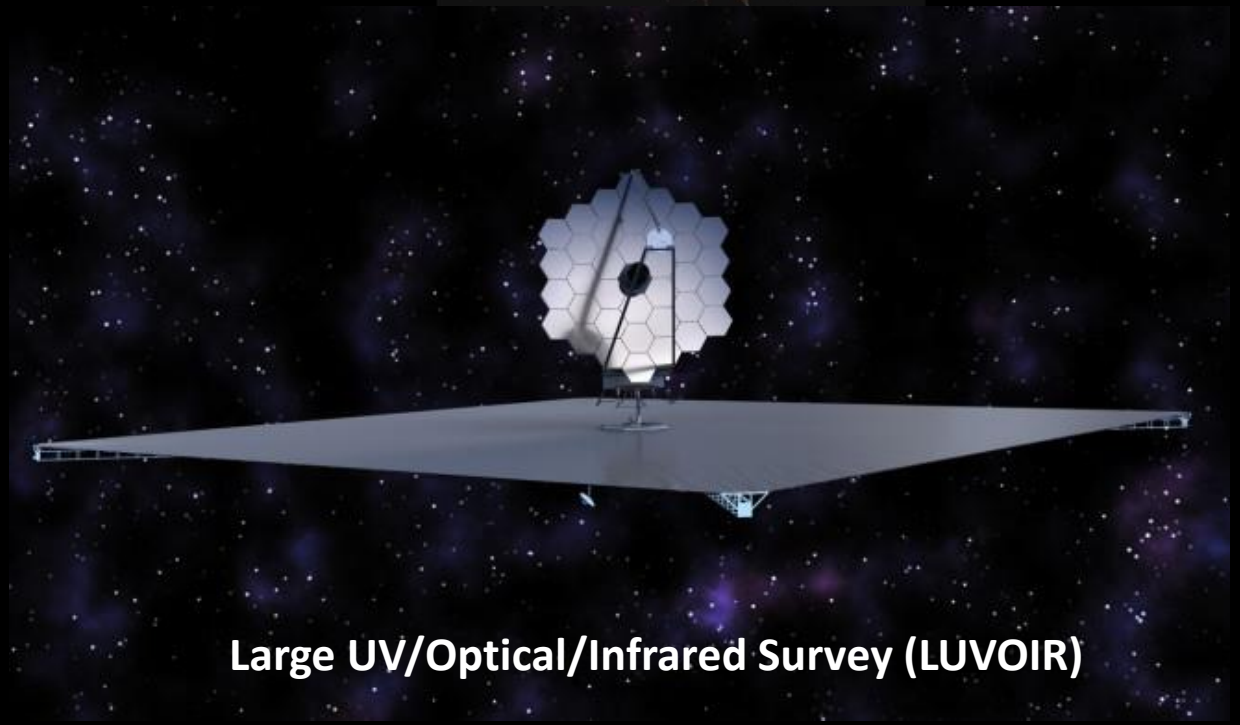
Concepts Under Study for Large Space Telescopes Capable of Studying Exoplanets in 2030s



Habitable Exoplanet Imaging Mission (HabEx)



Origins Space Telescope (OST)



Large UV/Optical/Infrared Survey (LUVOIR)

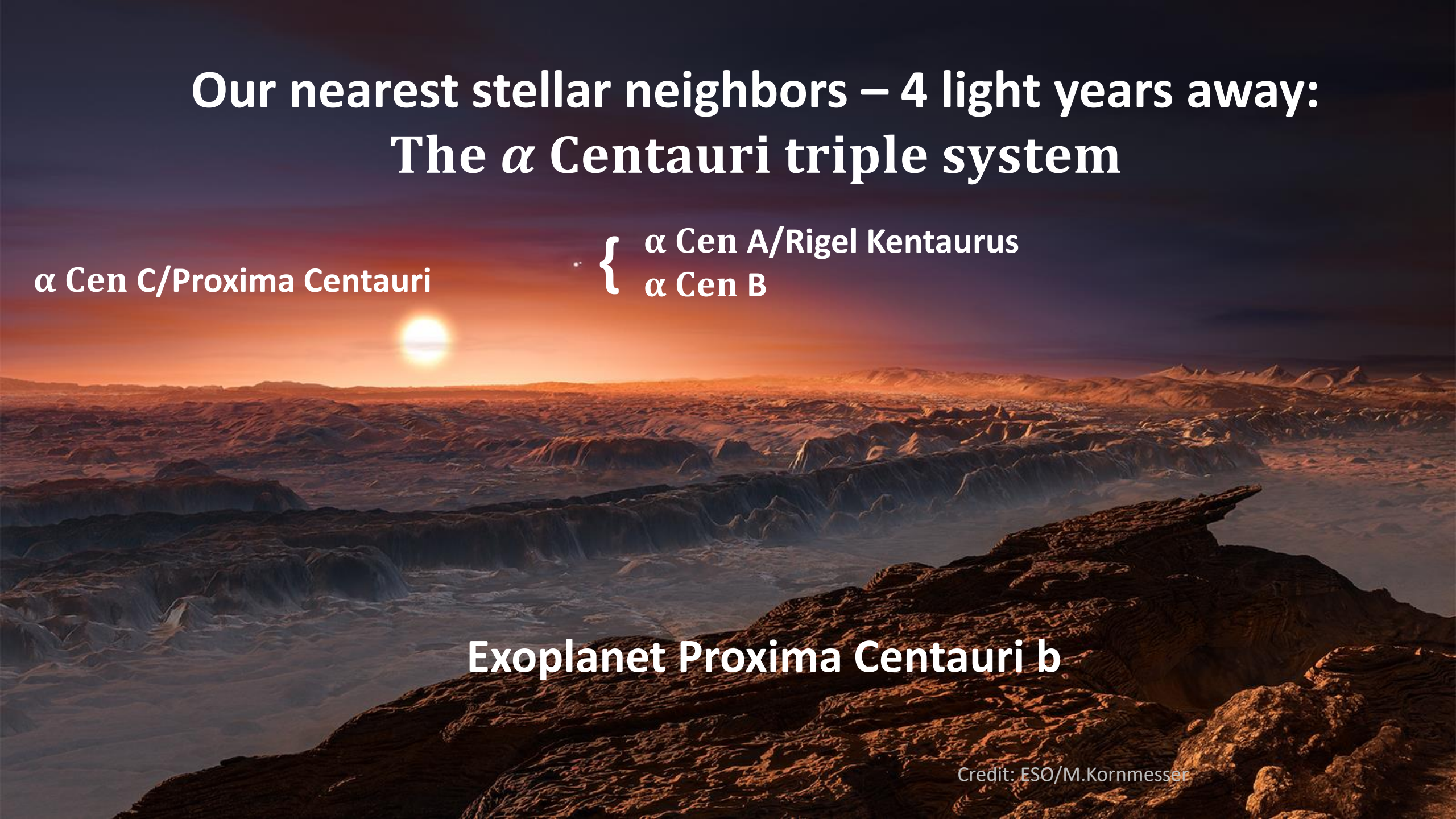
Credit: NASA

Our nearest stellar neighbors – 4 light years away:
The α Centauri triple system

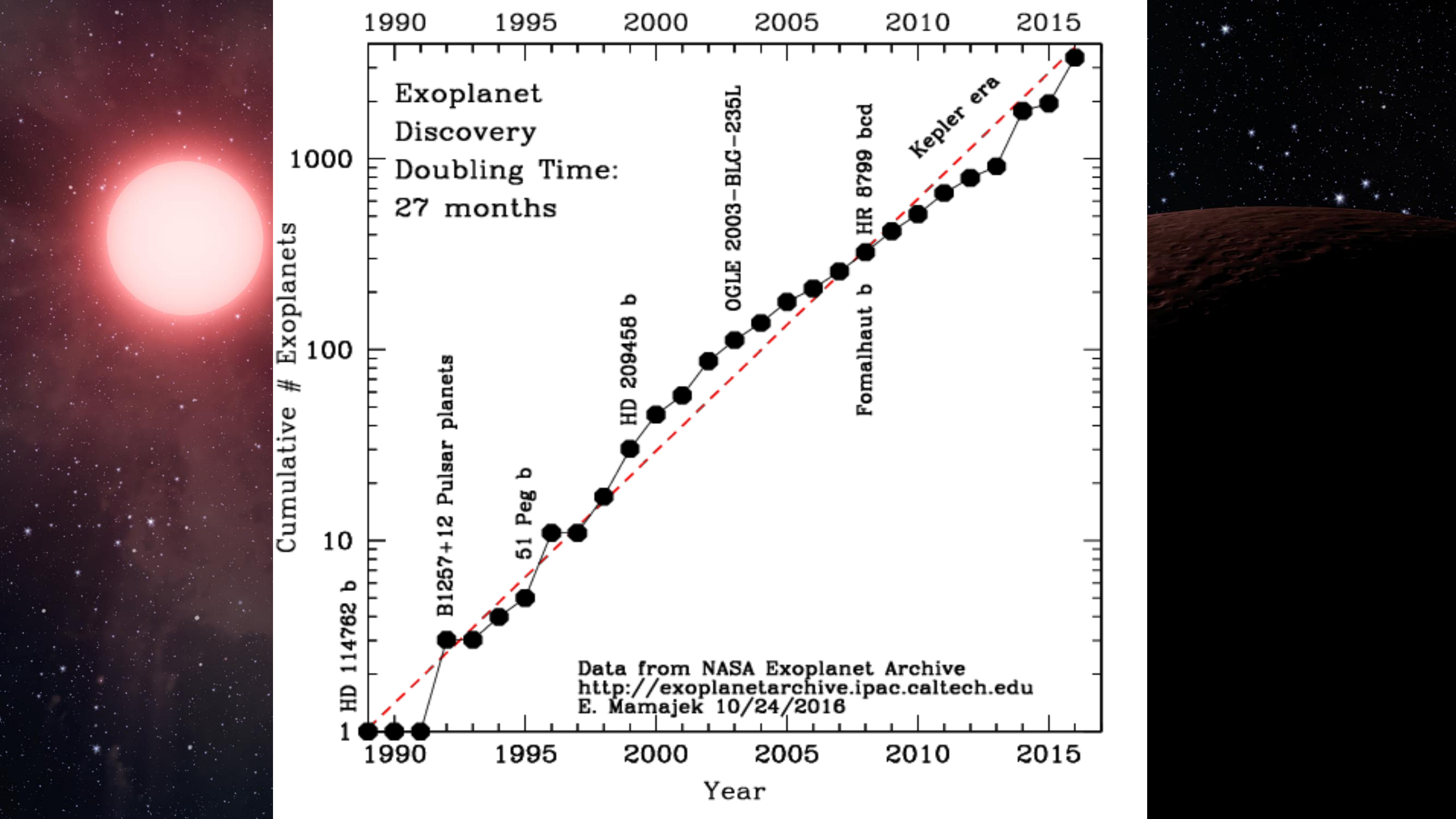
α Cen C/Proxima Centauri

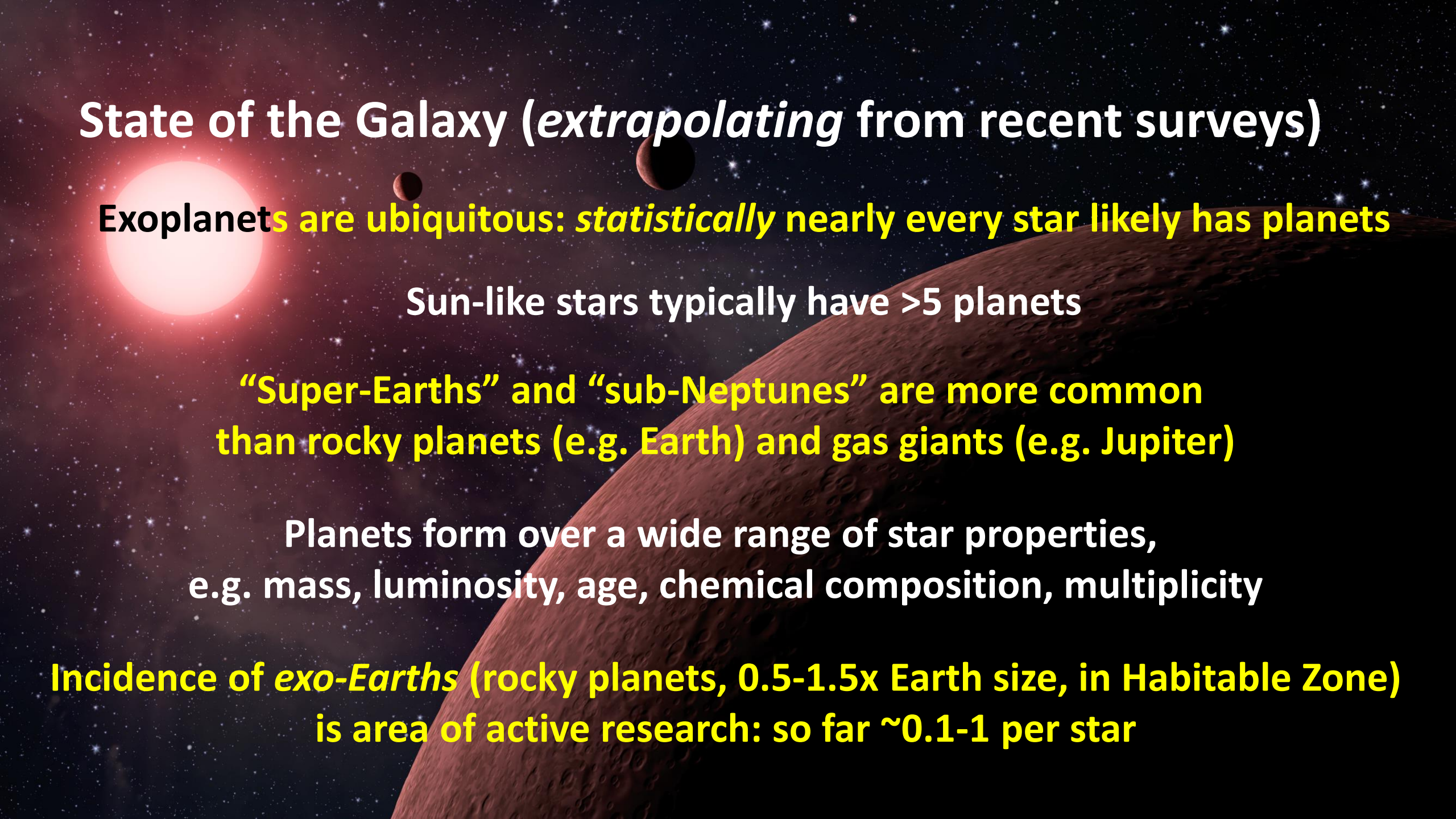
{ α Cen A/Rigel Kentaurus
α Cen B

Exoplanet Proxima Centauri b



Credit: ESO/M.Kornmesser


Exoplanet
Discovery
Doubling Time:
27 months
Cumulative # Exoplanets
Year
1
10
100
1000
1990
1995
2000
2005
2010
2015
HD 114762 b
B1257+12 Pulsar planets
51 Peg b
HD 209458 b
OGLE 2003-BLG-235L
Fomalhaut b
HR 8799 bcd
Kepler era
Data from NASA Exoplanet Archive
http://exoplanetarchive.ipac.caltech.edu
E. Mamajek 10/24/2016



State of the Galaxy (*extrapolating* from recent surveys)

Exoplanets are ubiquitous: *statistically* nearly every star likely has planets

Sun-like stars typically have >5 planets

"Super-Earths" and "sub-Neptunes" are more common than rocky planets (e.g. Earth) and gas giants (e.g. Jupiter)

Planets form over a wide range of star properties, e.g. mass, luminosity, age, chemical composition, multiplicity

Incidence of *exo-Earths* (rocky planets, 0.5-1.5x Earth size, in Habitable Zone) is area of active research: so far ~0.1-1 per star

Thank you!

For more on exoplanets:

https://exoplanets.nasa.gov/

NASA Exoplanet Archive
http://exoplanetarchive.ipac.caltech.edu/
Kepler & K2 exoplanet mission
https://kepler.nasa.gov/
NASA's Eyes app ("Eyes on Exoplanets")
http://eyes.jpl.nasa.gov/eyes-on-exoplanets.html

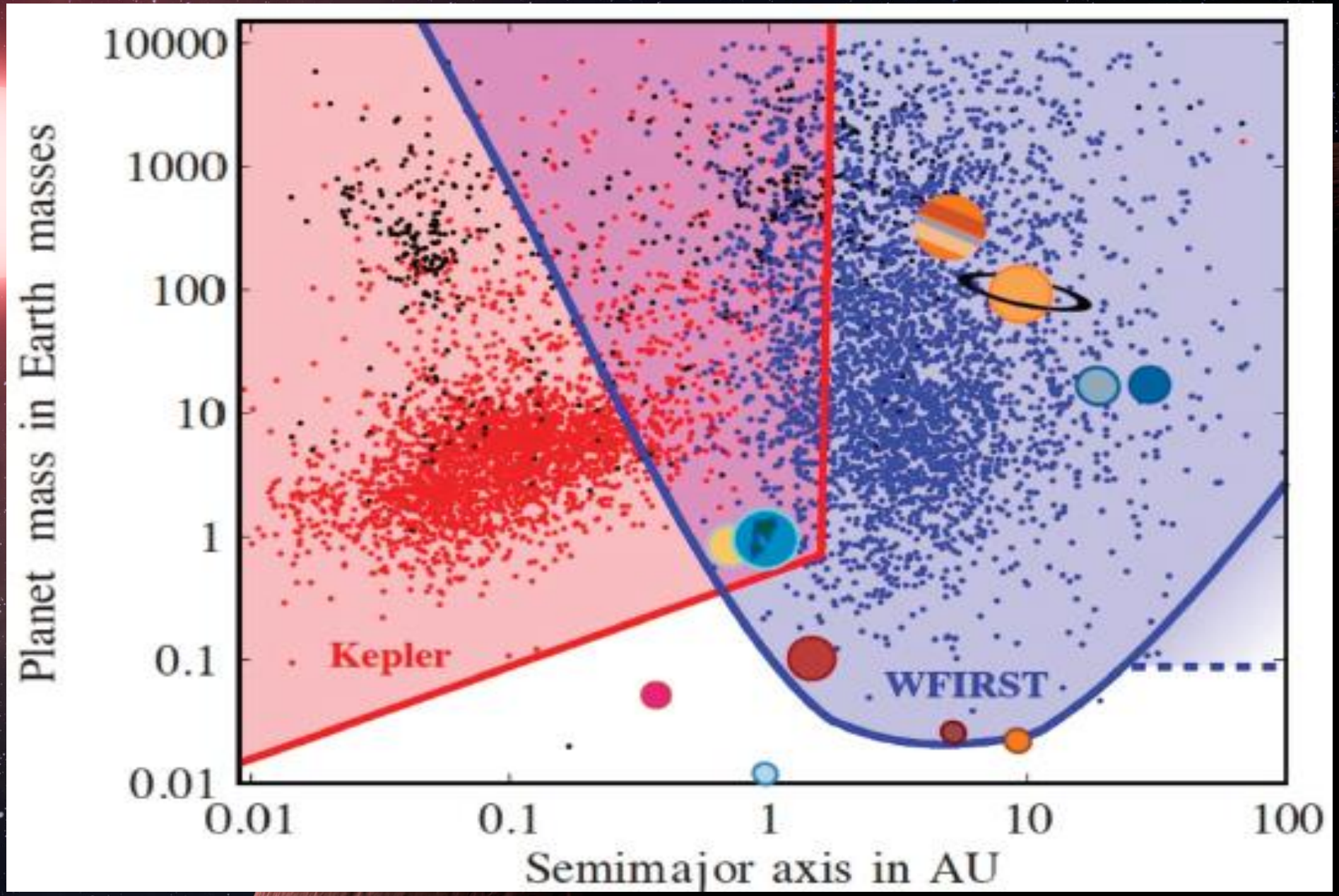
NASA Planetquest
@Planetquest

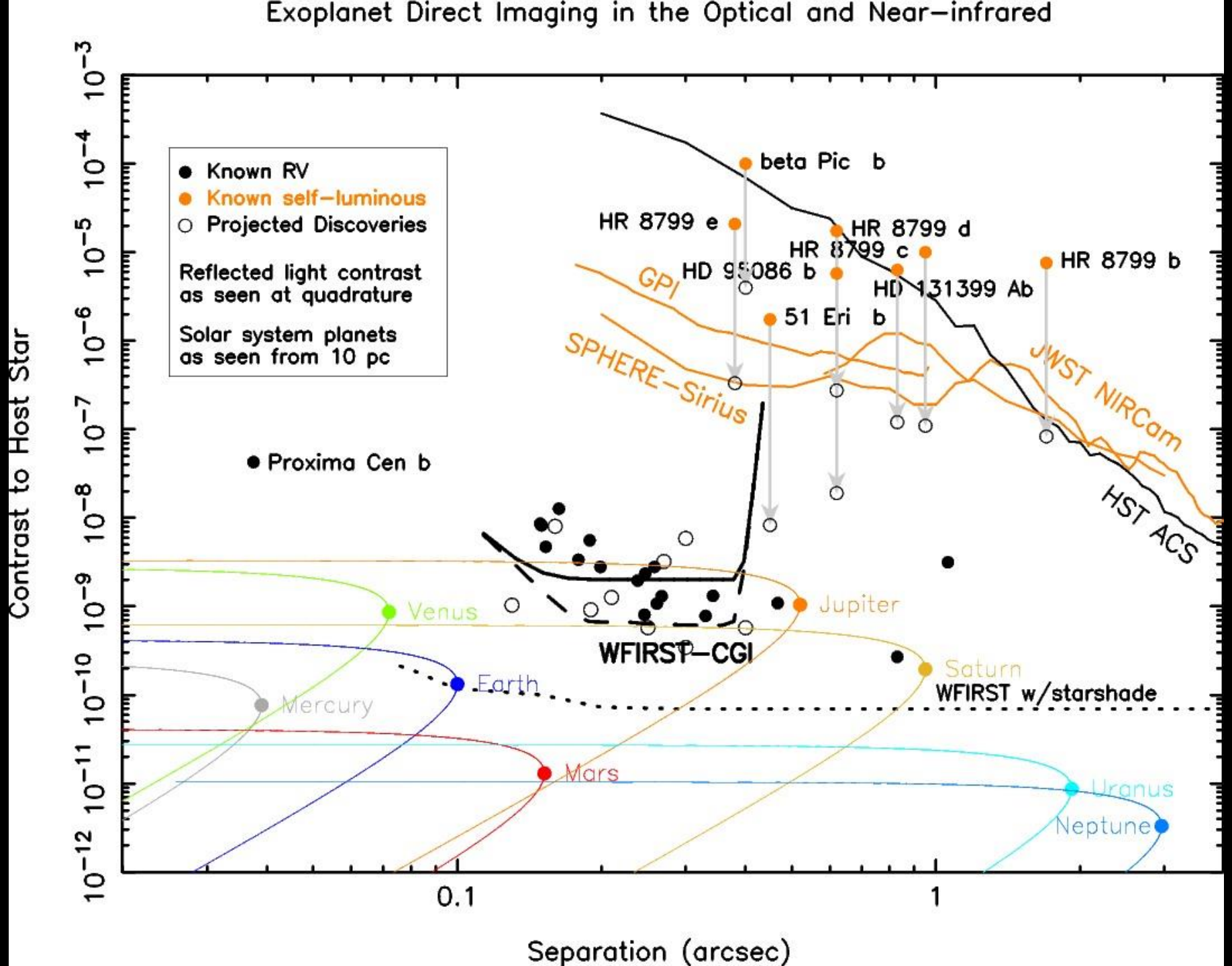
This work was carried out at the Jet Propulsion Laboratory, California Institute of Technology under contract with the National Aeronautics and Space Administration. *© 2017 All rights reserved.*

The names of 14 stars and 31 exoplanets
approved by the International Astronomical Union
nameexoworlds.iau.org

IAU

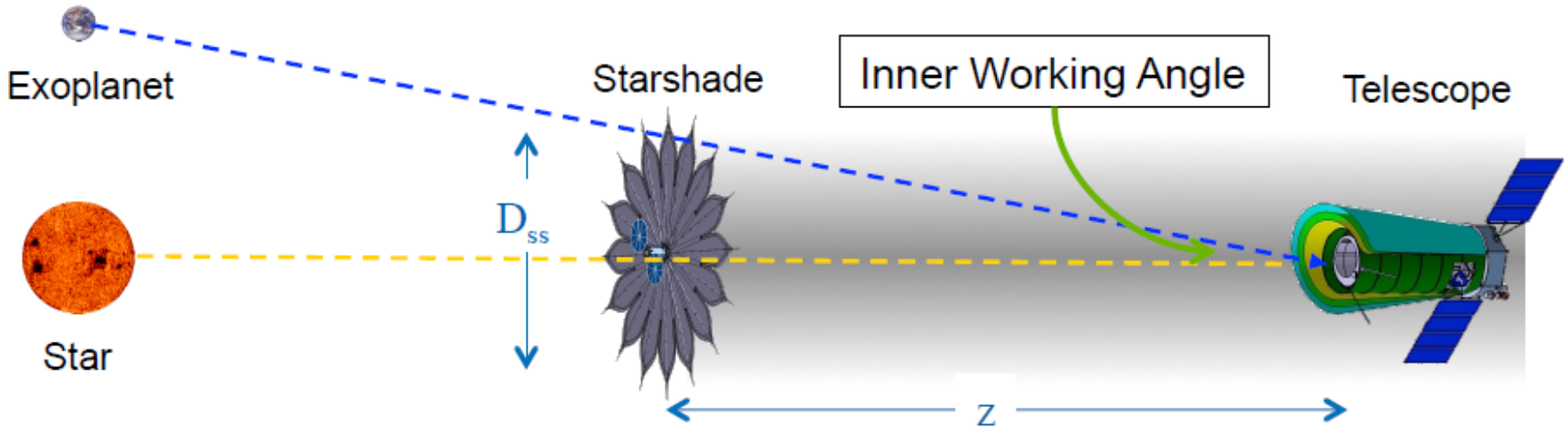
Microlensing with WFIRST will give statistical census of exoplanets on orbits similar to planets in our solar system





WFIRST Coronagraph: imaging large exoplanets on wide orbits around the nearest stars

Starshade concept



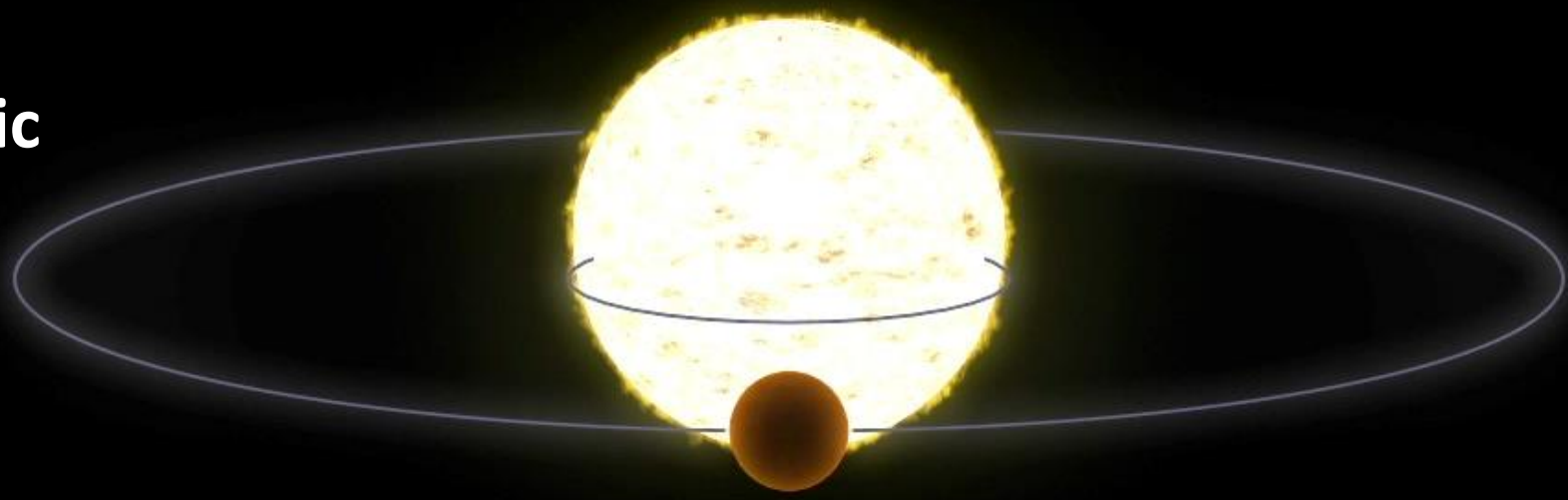
- Inner Working Angle is the closest separation of Planet and Star that we can expect to see with a given starshade
- For Hypergaussian starshade, this is approximately equivalent to:

$$IWA = \frac{D_{ss}/2}{z}$$

Credit: Steve Warwick, NGST

Techniques to detect planets around other stars

Astrometric Method



Credit: NASA

Credit: *ESO/M. Kornmesser/G. Coleman*

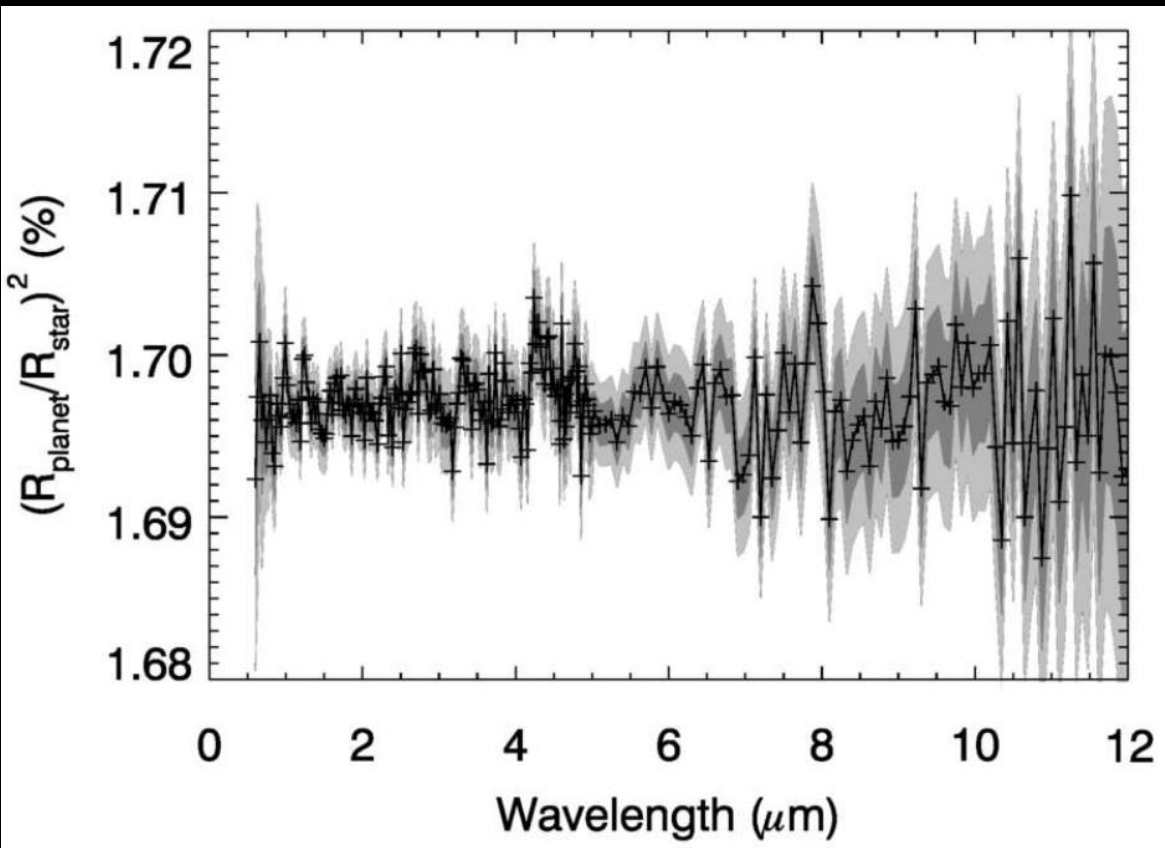
1995: A “Hot Jupiter” orbiting 51 Peg

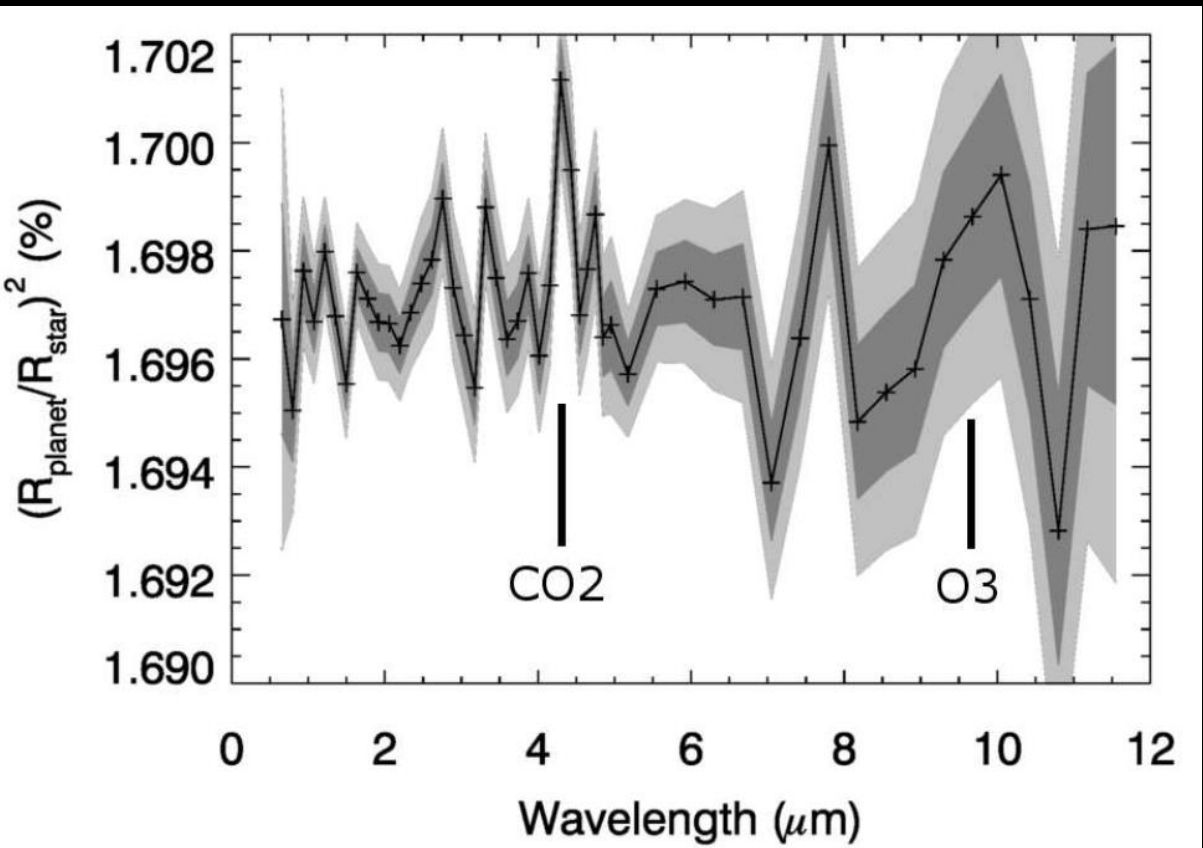
51 Peg b/
Dimidium

51 Peg A/
Helvetios

Credit: NASA/JPL-Caltech

JWST transit spectroscopy: looking for molecules in exoplanet atmospheres





Barstow+2015